NHTSA'S NATIONAL ADVANCED DRIVING SIMULATOR RESEARCH PROGRAM

W. Riley Garrott
Elizabeth N. Mazzae
Michael J. Goodman
National Highway Traffic Safety Administration
United States of America
Paper Number 05-0377

ABSTRACT

Since its completion, the National Advanced Driving Simulator (NADS) has been used for a variety of NHTSA research projects. NHTSA-sponsored research using the NADS has spanned a variety of topics including driver distraction, drivers' responses to vehicle component failures, and the effects of alcohol impairment on driving performance. The validity of the NADS has also been verified empirically. The NADS provides the computational capabilities and fidelity necessary to create complex driving situations with varying task demands with high repeatability. The use of the NADS also allows the inclusion of conflict situations that cannot safely be created in on-road experiments. NHTSA research utilizes these unique capabilities of NADS to address questions that cannot be addressed with on-road or test-track experimentation. This paper highlights NADS capabilities through descriptions of NHTSA research programs.

INTRODUCTION

Historically, a number of methods have been available for use in studying driver behavior and performance including: (1) observation of real world, "naturalistic," driving, (2) testing with instrumented vehicles on public roads, (3) testing with instrumented vehicles on test tracks, (4) low fidelity driving simulators, and (5) a variety of in-laboratory tests. However, frequently these methods do not have the capability to test drivers in safety critical situations with a high degree of realism. Test repeatability is also difficult to achieve with non-simulator methods, particularly in complex driving scenarios.

Thus, to improve NHTSA's ability to perform driver behavior and performance testing, the Agency decided in 1992 to build a high fidelity driving simulator in the U. S. – the National Advanced Driving Simulator (NADS). Such a simulator would benefit industry and academia as well as NHTSA. Therefore, following a site selection competition, the NADS was built by a partnership between NHTSA and the University of Iowa. The NADS became operational in January 2002.

OBJECTIVE

The objective of this paper is to outline the capabilities of the NADS and provide a description of the research programs that NHTSA has undertaken to date. The description of each research program will highlight the capabilities of NADS that were necessary to perform that particular program.

BASIC DESCRIPTION OF THE NADS

Reference [1] contains a comprehensive description of the NADS. The following brief description of NADS was excerpted from Reference [2] with minor modifications to accommodate changes since Reference [2] was written and improve clarity.

NADS is physically located on the University of Iowa's Oakdale Research Park in Iowa City, IA. It consists of a large dome in which entire cars and the cabs of heavy trucks and buses can be mounted. The dome is mounted on a six degree of freedom hexapod that is mounted on the large excursion motion base. The large excursion motion base provides 20 meters of both lateral and longitudinal travel and ∀330 degrees of yaw rotation. The resulting effect is that drivers feels acceleration, braking, and steering cues as if they were actually in a real vehicle. This greatly reduces the incidence of simulator sickness compared to simulators that have less motion capability.

The Motion System provides a combination of translational and angular motion that uses nine degrees of freedom to mimic scaled vehicle motion. The Motion System is coordinated with the Control Feel System (described below) to provide the driver with realistic motion and haptic cuing during normal driving and pre-crash scenarios. A "washout" filter is used so that the Motion System can correctly represent the specific forces and angular rates associated with vehicle motions for the full range of driving maneuvers.

Four additional actuators, one at each wheel of the vehicle, provide vertical vibrations. This simulates the feel of a real road. Without these actuators, driving on NADS would feel like driving on ice.

The Visual System provides the driver with a realistic field-of-view in all directions (including rearview mirror images). The driving scene is three-dimensional, photo-realistic, and correlated with other sensory stimuli. The Visual System database includes highway traffic control devices (signs, signals, and delineation), three-dimensional objects that vehicles encounter (animals, guardrails, pillars, etc.), high density, multiple lane traffic interacting with the driver's vehicle, common intersection types (freeway interchanges, overpasses, bridge structures, tunnels, railroad crossings, etc.), and roadway weather.

The Cab System holds the driver (participant) and the experimenter during testing. NADS has four vehicle "cabs" that can be used for testing: a Chevrolet Malibu (passenger car), a Ford Taurus (passenger car), a Jeep Cherokee (sport utility vehicle), and a Freightliner Century (heavy truck-tractor). For the passenger car and sport utility vehicle cabs, the entire vehicle is mounted inside the NADS dome. For the heavy truck-tractor, only a portion of the actual vehicle (the actual vehicle's cab) is present inside the dome. All vehicle cabs are equipped electronically and mechanically with the correct steering wheel, brake and throttle pedals (the Freightliner also has a clutch pedal), transmission lever, ancillary controls, entertainment system, air conditioning, gauges, and warning lights for their make and model.

The Control Feel System provides realistic steering wheel, brake, throttle, and clutch pedal, and transmission lever reactions in response to driver inputs, vehicle motions, and road/tire interactions. The Control Feel System is capable of power steering, power brakes, antilock brake systems (ABS), cruise control, and automatic and manual transmissions with different numbers of gears. The control feel cuing feedback has high bandwidth and no discernable delay or distortion associated with driver control actions or vehicle dynamics.

The Auditory System provides motion-correlated, three-dimensional, realistic sound sources coordinated with the driving situation. The Auditory System also generates vibrations to simulate vehicle/roadway interactions. The auditory database includes sounds emanating from the subject vehicle during operation, from other traffic, and from contact with three-dimensional objects that the subject vehicle may contact (traffic cones, orange barrels, etc.) This database also contains sounds and vibrations generated by driving on various types of roadways in a variety of weather conditions and from encountering joints, potholes, etc. on the road.

The Vehicle Dynamics System computes vehicle motions in response to driver control inputs, tire/road surface interactions, and the aerodynamic forces acting on the subject vehicle. Vehicle responses are computed for commanding the Motion, Visual, Cab, Control feel, and Auditory Systems. The NADSdyna vehicle dynamics simulation currently used by the NADS is a multi-body, high degree of freedom simulation based on the University of Iowa's Real-Time Recursive Dynamics code. Subsystem models are included to realistically emulate each vehicle's tires, brakes, ABS, steering, powertrain, and aerodynamics. NADSdyna models are available for a 1998 Chevrolet Malibu, a 2003 Ford Expedition, a 1994 Ford Taurus, a 1997 Jeep Cherokee, a 2002 Oldsmobile Intrigue, and a 1992 White-GMC heavy truck-tractor with a 53 foot long, 1992 Fruehauf van trailer. Hardware-in-the-loop modeling has been used to realistically emulate electronic stability control for two vehicles: the 2003 Ford Expedition and the 2002 Oldsmobile Intrigue.

NADSdyna has been extensively validated [3 through 14]. It can accurately predict vehicle motions during normal driving conditions, non-linear maneuvering, and during limit performance maneuvering such as might be encountered during extreme crash avoidance conditions (including spinout and incipient rollover).

PAST AND CURRENT NADS RESEARCH

The National Advanced Driving Simulator (NADS) has been used for a variety of NHTSA research projects. The types of research performed by NHTSA using the NADS have spanned a variety of topics, such as driver distraction, drivers' responses to vehicle component failures, the effects of alcohol impairment on driving performance, and the validity of the NADS. This paper contains summaries of all completed or in progress NADS projects that were directly run by NHTSA. Projects are listed in chronological order according to when the experimental data collection was performed. For the project mentioned here, the first three projects have been completed, the next two have completed data collection and final reports are currently being prepared, while the data are currently being collected for the last two projects.

Investigation of Driver Reactions to Tread Separation Scenarios Study

The first NHTSA study performed on the NADS was an investigation of driver reactions to tread separation scenarios. This study is fully documented in the NHTSA technical report "Investigation of Driver Reactions to Tread Separation Scenarios in the National Advanced Driving Simulator (NADS)," [2]. The following description of this study and its results is excerpted from [2] with minor modifications to improve clarity.

This research was performed to assess drivers' responses to simulated tire failures, specifically tread separations. The objective of this research was to evaluate the effects of the following independent variables on drivers' responses and the likelihood of control loss following simulated tread separation on one of the rear tires of a simulated sport utility vehicle traveling at high speed:

1. Vehicle understeer gradient
2. Prior knowledge of an imminent tire failure
3. Instructions on how to respond to a tire failure
4. Driver age
5. Location of tire that failed (left rear or right rear)

One hundred and eight participants each experienced two tire failures while driving on a straight, divided highway at approximately 75 mph with light surrounding traffic. Drivers were assigned to a single simulated vehicle condition having one of three understeer gradients. They experienced both simulated tire failures in that same vehicle. Vehicles with different understeer gradients are referred to as Vehicles 1-3. Vehicle 1 had an understeer gradient of approximately 4.7 deg/g with four non-failed tires. Vehicles 2 and 3 were modified from Vehicle 1 so that the resulting understeer gradients were 3.4 and 2.4 deg/g, respectively. Following tread separation for the left rear tire, the understeer gradients resulting from a right turn of these vehicles changed to 1.10, 0.09, and –1.17 deg/g, respectively.

The first tire failure presented was unexpected. Drivers were given no information about the possibility of tire failure; rather, they were told that they were evaluating the realism of the simulator. The second tire failure was expected, although drivers were given different amounts of information. Half of the participants were given specific instructions on how to respond following the second tire failure, while half were told only that one or more tire failures would likely occur.

Decreasing vehicle understeer gradient was strongly associated with the likelihood of control loss following both the unexpected and expected tire failures. Overall, the proportion of trials resulting in loss of vehicle control increased from 10 percent (Vehicle 1) to 35 percent (Vehicle 2) to 68 percent (Vehicle 3). Knowledge of the imminent tread separation reduced the overall probability of control loss from 55 percent to 20 percent. Drivers of Vehicle 3 were still much more likely to sustain a loss of vehicle control following the expected tread separation than were drivers of Vehicle 1 (39 percent loss of control versus 3 percent) and twice as likely to sustain loss of vehicle control following the expected tread separation than were drivers of Vehicle 2 (39 percent loss of control versus 19 percent).

Differences associated with vehicle understeer conditions observed in this study were large and consistent, independent of driver expectations, and varied only slightly across driver age groups. Thus it is fair to conclude that in the event of a complete rear-tire detread, the increased difficulty in vehicle handling and the associated increased likelihood of loss of vehicle control with decreasing vehicle understeer gradient generalize to real-world driving. However, it is also important to note that the model used in this study for the tire detreading event is a worst-case scenario (an extremely rapid, complete loss of tread giving the driver only minimal time to react while the detreading is actually occurring prior to the degradation of the tire's frictional capabilities).

This study was performed on the NADS for several reasons. Most importantly, NADS allows testing of the effects of tire tread separations at high speed (75 mph) to be performed without risk of injury to participants. Test track testing involving vehicle subsystem failures and resulting in limit maneuvers is too dangerous to be performed by members of the general public. In addition, tread separations could be performed repeatably in the NADS, something that is very hard to achieve on the test track. Another reason for using NADS was NADSdyna, can accurately predict vehicle motions up to the limits of vehicle performance, including loss of control. Finally, NADSdyna's tire parameters could be configured with minimal effort to permit accurate modeling of the forces and moments generated by a tire that had completely lost its tread.

Low Speed Turn NADS Validation Study

Low speed right-angle turns (of the type encountered at intersections) have traditionally been a problem for lower fidelity driving simulators. Difficulty in providing adequate motion cues to the driver and in low speed tire modeling have made this situation beyond the capabilities of many driving simulators. Due to its large excursion motion base (particularly its ∀330 degrees of yaw rotation) and because the NADSdyna tire model has been specially formulated to be able to provide accurate tire forces and moments at speeds down to 0.0 mph (an even when the vehicle is in reverse), the NADS was expected to be able to simulate low speed right-angle turns with sufficient validity to allow drivers to maintain precise control. However, initial use of the NADS demonstrated that there were still problems in accurately simulating these turns. Therefore, a small study was performed to determine the reasons for the remaining low speed turn problems.

For this study, a simulated urban street network was developed. Ten participants drove a designated route containing a total of six right-angle turns at intersections, three to the right and three to the left. Two of these turns, one to the right and one to the left, were made at intersections with stop signs so that the vehicle came to a complete stop prior to making the turn. For the other four turns, the drivers drove through the turns at whatever speed seemed natural to them. This speed was always very low, never exceeding 15 mph.

Comparison data were obtained by having a subset of the test participants perform right-angle turns at simulated intersections on the Transportation Research Center, Inc.'s Vehicle Dynamics Area (VDA). Participants drove the same vehicle that was simulated on the NADS. This research found that the handwheel steering angle of drivers on the NADS was overshooting the values observed during testing on the VDA. Drivers then had to take corrective steering actions to achieve their desired course. The reason for the handwheel steering angle overshoot was determined to be the lack of visual delay compensation on the NADS. (Due to hardware limitations, the NADS Visual System displays a visual scene that lags the actual visual scene by approximately 100 milliseconds.) A visual delay compensation subsystem was then added to NADS. This visual delay compensation system is documented in [15].

Additional NADS testing was performed following the addition of the visual delay compensation system. Figure 1 shows handwheel steering angle versus distance traveled before and after the addition of visual delay compensation. The reduction in steering overshoot is apparent. Figure 2 is close up of the handwheel steering angle versus distance traveled at one right-angle turn. While the NADS without visual delay compensation had no steering overshoot for this turn, as Figure 2 shows there was a substantial amount of unrealistic steering oscillation. This testing showed that the driver steering, vehicle yaw rate, and vehicle trajectory on NADS during a low-speed, right angle turn was now very realistic.

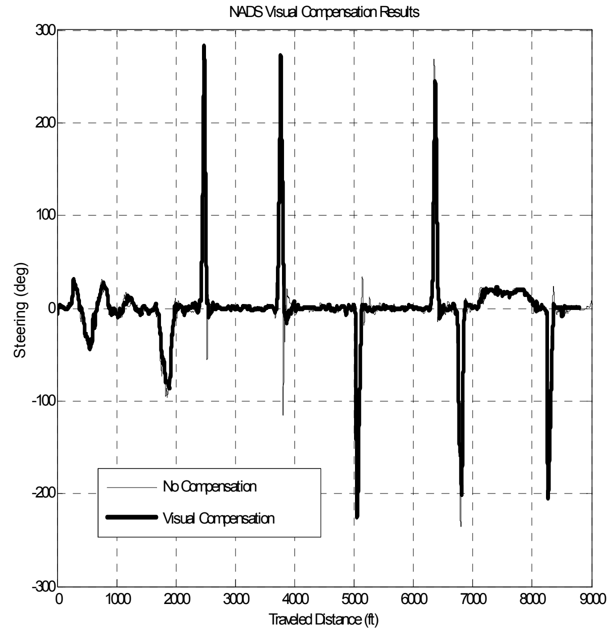

Figure 1. Handwheel steering angle versus distance traveled for a typical low speed turn test.

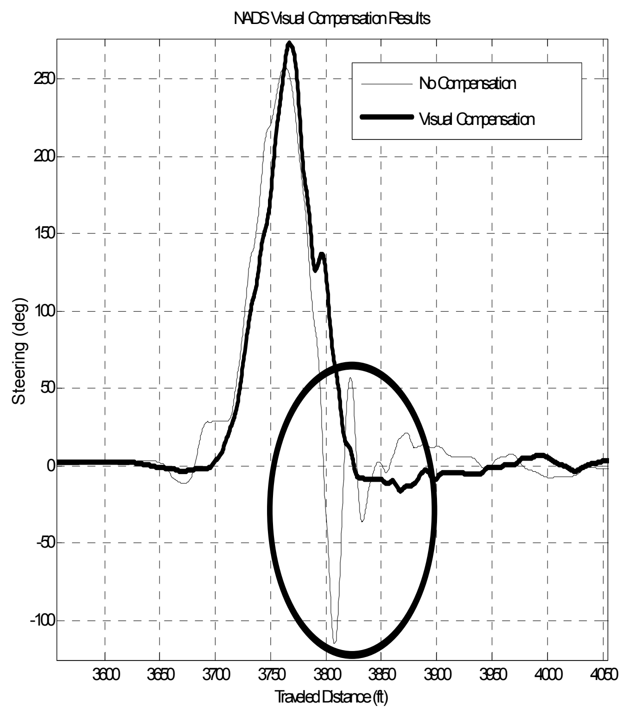

Figure 2. Close up of handwheel steering angle versus distance traveled during one typical right-angle turn.

Examination of the Distraction Effects of Wireless Phone Interfaces Using NADS – Freeway Study

In recent years, studies have shown that use of wireless phones while driving contributes to crashes. Numerous efforts are under way to pass legislation that makes it illegal to use hand-held wireless phones while driving. The assumption behind this move is that any technology that reduces the visual-manual demands of wireless telecommunications must be safer, since the driver can keep both hands on the wheel and both eyes on the road. However, research has not supported this assumption.

This study investigated the effects of wireless phone use on driving performance and behavior. The study had two primary objectives: (1) to assess the distraction potential associated with the use of wireless phones while driving, and (2) to determine whether distraction potential was related to the specific phone interface used. In particular, the experiment addressed the question of whether Hands-Free operation substantively affected the distraction potential associated with wireless phone use while driving. In addition, the experiment investigated whether voice-activated dialing affected distraction potential while driving. The secondary objective was to determine whether the distraction potential associated with phone use varies with driver age.

This study was performed on the NADS for two main reasons. First, NADS allows drivers to be subjected to potentially dangerous driving events (vehicles cutting-in close to the subject vehicle, lead vehicle braking, merging) while talking on the wireless phone. While these events do occur during real world driving, they happen so infrequently that studying them during actual (naturalistic) driving is almost impossible. Second, NADS provides the experimental control to allow a specific driving scenario to be repeatably presented to multiple subjects. This repeatability allows more sophisticated analyses of data to be performed than is the case for public road driving. Further more, liability issues would arise if a researcher directed a participant of an on-road study to perform a task and a crash resulted.

The procedure involved 54 participants driving a freeway route scenario on the NADS with each of three different wireless phone interface types: Hand-Held, Hands-Free with headset, and Hands-Free speaker kit with voice dialing. Phone conversations consisted of performance of a verbal interactive task involving judging whether sentences made sense and later recalling words from each sentence.

Each participant completed a single session lasting 3 hours. The participant drove the same scenario route three times, once for each phone interface. The order of presentation of phone interface conditions was randomized. Each traversal of the route involved one incoming and one outgoing call. The order of presentation of incoming and outgoing calls was balanced.

The route consisted of a four-lane divided freeway with a 65-mph speed limit with traffic present. The route generally consisted of four straight segments of nearly equal length joined by right-side interchanges requiring exiting and merging behavior. The treatment drives were approximately 15 minutes in length and required participants to drive three segments of the divided freeway route. The route segments corresponded, respectively, to the incoming phone call, outgoing phone call, and baseline (no call) periods. Each route segment involved a series of interactions between the driver and the scenario vehicles (i.e., events). Events included a sudden lead-vehicle cut-in (LV cut-in), sudden braking by the lead vehicle (LV brake), a car following event, and a merge. Each traversal of the route was associated with a different order of events. The intention of the scenario design was to overlap the events with the 3.5-minute conversation task periods. Each participant also experienced a brief final event driving involving a more critical lead vehicle-braking event.

Results showed that wireless phone use impaired aspects of driving performance. In particular:

1. Phone use while driving degraded driving performance, particularly during car following. The simulated phone conversation was associated with a significant delay in responding to lead vehicle speed changes. Phone conversation also degraded vehicle control, as reflected by increased steering error and increased one measure of driver workload. Drivers spent less time planning for merge events while engaged in the phone task.
2. Overall, there were modest differences among interface conditions during the conversation task. The hand-held phone interfered with steering and lane position more than the hands-free interfaces.
4. Neither older nor younger drivers exhibited consistently worse performance due to simulated phone conversation.
5. Analysis of the final event scenario revealed significant differences for some dependent measures. Hypothesized effects related to phone interface were complicated by significant interactions between phone interface and age. For first response to the final brake event, participants in the hand-held condition responded significantly faster than those in the hands-free and no-phone conditions, contrary to hypothesis. These results appear to agree with results of the previously mentioned on-road study [16] that

showed that drivers looked forward more with hand-held than with hands-free.

Results also showed that the wireless phone task performance differed as a function of phone interface. More specifically:

1. Although participants rated the Hand-Held interface to be most difficult to use, this interface was associated with the fewest dialing errors (in terms of the number of attempts per dialing trial).
2. Participants' feelings that the Hand-Held interface was the most difficult to use were also not supported by dialing time results, which showed that the Hand-Held interface was associated with significantly faster dialing times than the other two interfaces for all three age groups. Shorter dialing times for the Hand-Held interface may be attributable to participants' prior experience with Hand-Held wireless phones, which was approximately 6 years on average. However, it should be noted that the length of time required to perform voice digit dialing depends on the interface being used. Voice digit dialing was chosen for implementation in this study since it provided the most direct comparison between manual and voice dialing.
3. Conversation task performance did not differ as a function of phone interface.
4. Age was the only examined variable significantly related to phone task performance, with younger individuals performing better than older individuals.

This study is fully documented in two NHTSA technical reports, "Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator – Preliminary Report on Freeway Pilot Study," [17] and "Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator - Final Report on a Freeway Study," [18] and one Human Factors and Ergonomics Society Paper, "Hand-Held or Hands-Free? The Effects of Wireless Phone Interface Type on Phone Task Performance and Driver Preference" [19]. Most of the preceding description of this study and its results was excerpted from [18] with minor modifications to provide additional information and improve clarity.

Examination of the Distraction Effects of Wireless Phone Interfaces Using NADS – Arterial Study

NHTSA also conducted research to investigate the effects of wireless phone use on driving performance and behavior in an urban arterial driving environment. The urban arterial environment required a more active style of driving and employed a more dynamic visual scene.

The main objective of the research was to collect information useful in the assessment of 1) the distraction potential of wireless phone use while driving, and 2) the difference in distraction caused by the use of a hands-free wireless phone interface versus that associated with use of a hand-held interface. Of particular interest was whether using hand-held wireless phone interfaces (e.g., dialing, answering, conversation) while driving degrades driving performance more than does hands-free wireless phones. In addition, the research addressed the question of whether younger and/or older drivers exhibit worse driving performance during wireless phone task components than middle-aged drivers. Lastly, the research examined whether drivers glance away from the forward roadway more when using a hands-free wireless phone interface than they did when using a wireless phone in a hand-held configuration.

Fifty-four participants drove an urban arterial driving scenario on the NADS with each of three different wireless phone interface types. Like the freeway study, phone conversations consisted of performance of a verbal interactive task involving judging whether sentences made sense and later recalling words from each sentence.

Each participant completed a single session, in which the same basic route was driven three times, once with each phone interface. The order of presentation of phone interface conditions was varied systematically. Each traversal of the route involved one incoming call, one outgoing call, and a baseline period, as well as a unique order of scenario events. The order of presentation of incoming and outgoing calls was balanced.

The route consisted of four-lane undivided arterial roadway with a 45-mph speed limit and other traffic. The route required approximately 15 minutes to drive and consisted of three segments of equal length. Each segment corresponded to an incoming call, outgoing call, or baseline driving period.

Each segment contained a "between towns" section and an "in town" section. Between-town sections were characterized by mild, alternating curves. A visual target detection task was presented during between town sections in which participants had to press the vehicle's horn button when they spotted a pedestrian wearing a shirt with an "I" on it amongst a number of other similarly dressed pedestrians. In-town sections consisted of straight portion of roadway lined with buildings and vehicles. During in town sections, events were presented including incursions, occasional static vehicles blocking the participant's travel lane, and changing traffic signals that required drivers to respond to avoid a collision or running a red light.

Dependent measures used to characterize driving performance included reaction time in response to discrete events (i.e., conflict events and traffic lights), as well as reaction time and accuracy of responses for the visual target task. Phone task performance measures included dialing time, number for dialing errors, answering time, and the number of correct judgments and recalled terms for the conversation task. Participants also completed a post-drive questionnaire used to report perceived difficulty of driving and phone tasks, as well as preferences regarding phone interfaces and related features.

Data analysis is currently underway for this study. Analyses are focused on assessing the impact of phone use on individual measures of driving performance. Analyses will highlight the degree to which phone use affects a driver's ability to respond to conflict events and objects in their visual environment. The anticipated time frame for release of a final report on this study is mid-2005.

The Urban Arterial Wireless Phone Interface Study was performed on the NADS for the same two main reasons as was the Freeway Wireless Phone Interface Study: ability to subject drivers to potentially dangerous driving events while talking on the wireless phone, to be able to tell the participant when to use the phone without risk of liability issues, and to have repeatable driving conditions.

Older Driver NADS Validation Study

Older drivers are a group of special interest and concern for NHTSA. Due to the aging of America, there is expected to be a substantial increase in the number of older drivers. According to the United States Census Bureau, by the year 2020 "about 50 million Americans will be aged 65 or older – roughly one-fifth of the driving-age population." [20]

In preparation for the initiation of an older driver research program on the NADS, NHTSA is conducting a preliminary investigation comparing older driver behavior and performance on the NADS with that on similar public roads. For the planned, upcoming, NHTSA older driver research, it is essential that older driver behavior and performance in the NADS be comparable to that which is observable in real vehicles on real roads.

Validation studies comparing driver behavior and performance in the NADS to that while driving on public roads have, to date, only been conducted for a very limited number of driving situations. The assumption made by researchers is that because the NADS simulates the vehicle and its visual and kinesthetic environment with high fidelity, driving performance and behavior on the NADS must be similar to that of drivers on similar public roads.

Because older drivers generally tend to be less familiar with and less receptive to technology, researchers are concerned that their behavior and performance in the NADS may not be comparable with that seen on public roads.

The specific objectives for this program are:

1. To demonstrate that driving performance and behavior on the NADS is, in general, comparable to driving performance and behavior on public roads for all ages of drivers.
2. To determine whether there are any older driver specific problems in driving on the NADS.

The fundamental paradigm for this research was for test participants to drive an instrumented vehicle over a designated course on public roads and through a test track course (the "Actual Road" drive). Either immediately before or just after the Actual Road drive, participants drove the NADS through a simulated version of the same course (the "NADS" drive). Data collected during the Actual Road and the NADS drives were then compared. The following independent variables were examined:

1. Participant age. Three age groups were used 35–55, 60–70, and 75+. Gender was balanced for each age group.
2. Test vehicle (NADS or instrumented vehicle). To permit within-subjects testing, NHTSA's Vehicle Research and Test Center sent a suitably instrumented Chevrolet Malibu to Iowa where participants drove it on public roads and through a test track course.
3. Driving situation. Driving situations included freeway driving, straight and curved two-lane road driving with a speed limit of 25 and 55 mph, right-angle turns with and without stop signs, approaching/leaving a traffic light, driving through a simulated construction zone, and driving through a handling course delineated by traffic cones.
4. Run repetition. To check consistency of driver behavior and performance, a limited number of test participants drove the course, both on the NADS and on public roads/test track, once per day for five days (not necessarily consecutive).

The test matrix for the main test was a double test matrix. The first matrix involved twelve participants in each of the three age categories performing all driving situations in both the simulator and on the public road/test track. The second matrix involved a subset (four) of the same twelve performing the same driving situations another four times for both the simulator and public road/test track

Data analysis and report writing for this study is currently in progress. The anticipated time frame for release of a final report on this study is mid-2005.

Impairment Due to Various BAC Levels Study

NHTSA estimates that in 2000, alcohol was involved in 40 percent of fatal crashes as well as in eight percent of all crashes and that about three of every 10 Americans will be involved in an alcohol-related crash at some time during their lives. Much of the information available about the impact of alcohol on safety is from collision statistics where someone has been injured or killed. This data frequently does not tell investigators what led to the crash. Thus, to investigate the degree of impairment associated with particular blood alcohol concentrations (BAC) NHTSA is conducting a research program using the NADS. This work will examine the effects of alcohol in situations that are over-represented for alcohol-related crashes. This data can be used to develop countermeasures to reduce the frequency and severity of alcohol related crashes. The key advantage of using the NADS for this research is its high fidelity and the ability to examine the effects of alcohol on driving performance in a safe setting.

Efforts to date for this project have focused on sensitivity testing. Sensitivity testing examines whether or not a given driving scenario is sensitive to the effects of alcohol. This information is vital for the development of efficient driving scenarios that will be used for majority of the testing.

Following sensitivity testing, testing will be conducted to examine impairment associated with various levels of BAC, ranging from 0.02 to 0.08 in 0.02 increments. The ‘no alcohol use’ case (BAC of 0.00) will also be tested. Other independent variables will include driver age (younger, middle, older) and different drinking practices (heavy drinker, light drinker). Dependent variables will include a full set of vehicle control variables along with driver reaction times to various events.

In future testing, drivers will experience variations in environmental conditions and roadway situations such as denser traffic and roadway types and will be given realistic in-vehicle tasks such as talking on a cell phone, eating, drinking, or changing a CD while driving at various BAC levels. Since NHTSA estimates the rate of alcohol involvement in fatal crashes is more than three times as high at night as during the day, testing will examine how time of day influences the degree to which the BAC level degrades driving performance.

Electronic Stability Control Effectiveness Study

In late 2004, NHTSA began a research program to investigate the potential benefits of Electronic Stability Control (ESC) systems from the perspective of how drivers utilize such as system. This research seeks to assess how drivers use ESC and how ESC affects drivers’ ability to avoid crashes. In addition, this research will allow the examination of drivers’ reactions to ESC activation on the NADS.

Electronic stability control (ESC) is an electronic, active-safety system designed to help the driver maintain vehicle control under adverse conditions. ESC uses sensors to detect when the motion of the vehicle differs from what the drivers inputs suggest is desired and applies the brakes at individual wheels to correct the vehicle’s motion. Recent crash data studies from Germany and Japan have shown significant crash reductions with ESC systems. NHTSA has an interest in assessing this technology to determine whether these benefits might also be attainable in the U.S. NHTSA is currently conducting a comprehensive program of ESC hardware and performance testing. Using instrumented vehicles, maneuvers that may be sensitive to ESC intervention are being run with and without ESC on a test track to identify differences in stability as a function of ESC presence or absence. While ESC may show benefits in hardware testing, NHTSA is interested in examining the extent to which average drivers can take advantage of ESC. Since the largest benefit of ESC is achievable on low coefficient of friction surfaces and curves, placing average drivers in this type of roadway environment is of great interest.

NHTSA is currently developing plans to use NADS to examine how ESC affects average drivers’ ability to avoid crashes. This research will assist NHTSA in understanding for which situations (i.e., event type and pavement conditions), drivers (age), and vehicle types ESC is most helpful. Use of NADS will allow drivers to be put into crash-imminent situations with no danger of injury. Research results are hoped to provide insight as to what characteristics of operation equate to a “good ESC system.” Lastly, this research will allow the examination of drivers’ reactions to ESC activation on the NADS. Experimentation for this research will occur in mid-2005. Data analysis and report writing for this study is currently in progress. The anticipated time frame for release of a final report on this study is early 2006.

SUMMARY

Since it became operational in January 2002, NHTSA researchers have used the NADS to study a diverse collection of research topics. Topics studied include driver distraction, drivers’ interactions with vehicle subsystems and their responses to subsystem failures, the effects of alcohol-related impairment on driving performance, and the validity of the NADS.

The NADS provides the computational capabilities and fidelity necessary to create complex driving situations with varying task demands with high repeatability. The use of the NADS also allows the inclusion of conflict situations that cannot safely be created in on-road experiments. NHTSA research utilizes these unique capabilities of NADS to address questions that cannot be addressed with on-road or test-track experimentation.

REFERENCES

1. National Highway Traffic Safety Administration and The University of Iowa, "NADS: National Advanced Driving Simulator, The Most Sophisticated Driving Simulator in the World," June 2002
2. Ranney, T.A., Heydinger, G.J, Watson, G., Salaani, M.K., Mazzae, E.N., and Grygier, P.A., "Investigation of Driver Reactions to Tread Separation Scenarios in the National Advanced Driving Simulator (NADS)," DOT HS 809 523, November 2002
3. Garrott, W. R., Grygier, P. A., Chrstos, J. P., Heydinger, G. J., Salaani, M. K., Howe J. G., and Guenther, D. A., "Methodology for Validating the National Advanced Driving Simulator's Vehicle Dynamics (NADSdyna)," SAE Paper No. 970562, February 1997
4. Chrstos, J. P. and Grygier, P. A., " Experimental Testing of a 1994 Ford Taurus for NADSdyna Validation," SAE Paper No. 970563, February 1997
5. Salaani, M. K., Heydinger, G. J., and Guenther, D. A., "Validation Results from Using NADSdyna Vehicle Dynamics Simulation," SAE Paper No. 970565, February 1997
6. Salaani, M. K., Chrstos, J. P., and Guenther, D. A., "Parameter Measurement and Development of a NADSdyna Validation Data Set for a 1994 Ford Taurus," SAE Paper No. 970564, February 1997
7. Salaani, M. K. and Heydinger, G. J., "Powertrain and Brake Modeling of the 1994 Ford Taurus for the National Advanced Driving Simulator," SAE Paper No. 981190, February 1998
8. Salaani, M. K., "Vehicle Dynamics Modeling for the National Advanced Driving Simulator of a 1997 Jeep Cherokee," SAE Paper No. 1999-01-0121, March 1999
9. Salaani, M. K. and Heydinger, G. J. "Model Validation of the 1997 Jeep Cherokee for the National Advanced Driving Simulator," SAE Paper No. 2000-01-0700, March 2000
10. Salaani, M. K., Heydinger, G. J., and Grygier, P. A., "Parameter Determination and Vehicle Dynamics Modeling for the NADS of the 1998 Chevrolet Malibu," March 2001, SAE Paper 2001-01-0140
11. Salaani, M. K., Grygier, P. A., and Heydinger, G. J., "Model Validation of the 1998 Chevrolet Malibu for the National Advanced Driving Simulator," March 2001, SAE Paper 2001-01-0141
12. Salaani, M.K., Heydinger, G.J, and Grygier, P.A., "Heavy Tractor-Trailer Vehicle Dynamics Modeling for the National Advanced Driving Simulator," SAE Paper 2003-01-0965
13. Salaani, M.K., Heydinger, G.J, and Grygier, P.A., "Evaluation of Heavy Tractor-Trailer Model used in the National Advanced Driving Simulator," SAE Paper 2003-01-1324
14. Papelis, Y.E., Brown, T., Watson, G., Holz, D., and Pan, W. "Study of ESC Assisted Driver Performance Using a Driver Simulator," National Advanced Driving Simulator Document ID N04-003-PR, April, 2004
15. Salaani, M.K., Heydinger, G.J, Grygier, P.A., and Garrott, W.R., "Transport Delay Compensation for the Image Generator Used in the National Advanced Driving Simulator," IMECE 2003-42975, ASME International Mechanical Engineering Congress, November 15-21, 2003 Washington, D.C.
16. Mazzae, E.N., Baldwin, G.H., and Ranney, T.A., "Wireless Phone and AutoPC Related Technology: Driver Distraction and Use Effects on the Road," DOT 809 752, November 2004
17. Ranney, T.A., Watson, Mazzae, E.N., Papelis, Y.E., Ahmad, O., and Wightman, J.R., "Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator – Preliminary Report on Freeway Pilot Study," DOT HS 809 737, April 2004
18. Ranney, T.A., Watson, Mazzae, E.N., Papelis, Y.E., Ahmad, O., and Wightman, J.R., "Examination of the Distraction Effects of Wireless Phone Interfaces Using the National Advanced Driving Simulator – Final Report on a Freeway Pilot Study," DOT HS 809 787, September 2004
19. Mazzae, E.N., Ranney, T.A., Watson, and Wightman, J.A., "Hand-Held or Hands-Free? The Effects of Wireless Phone Interface Type on Phone Task Performance and Driver Preference," Human Factors and Ergonomics Society Paper, September 2004
20. Rickertsen, L., "Clear as Day", pp 104-106, Traffic Technology International, Oct/Nov 2004